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DEVELOPMENT OF RESEARCH ON ATMOSPHERIC CIRCULATION IN OUR COUNTRY IN THE PAST TEN YEARS

- COMMUNIST CHINA -

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DEVELOPMENT OF RESEARCH ON ATMOSPHERIC CIRCULATION IN OUR COUNTRY IN THE PAST TEN YEARS

[The following is a translation of an article written by Yeh Tu-cheng and Hsieh Kuang-tao, appearing in Ch'i-hsieng Hsueh-pao (Journal of Meteorology), Peiping, Vol XXX, No 3, October 1959, pages 263-276.]

Since the reconstruction of our country, especially during the three years of rehabilitation of the national economy, meteorological have concentrated their efforts on developing meteorological work and the urgently needed weather forecasting, because New China has inherited very little from Old China as far as meteorological studies are concerned. Meanwhile, however, theoretical research has not been neglected.

The results of research on atmospheric circulation during the past ten years have the following principal aspects:

(1) The basic situation and characteristics of atmospheric circulation in summer and winter in East Asia were already clearly ascertained; (2) some major physical processes of China's weather were partially understood; and(3) the major factor controlling weather in China has been detected, though it is still in a rudimentary stage.

Before liberation, research in atmospheric circulation in East Asia was practically nonexistent. Only as recently as in 1948 were better maps of surface air circulation in East Asia and of average monthly air circulation above three kilometers published. Prior to that year, some research had been done on the advance and retreat of the summer monsoon. During that time, there were only a few weather stations and their records were not very representative. Such work, therefore, could not describe the true picture of atmospheric circulation in East Asia.

Since liberation, because of the rapid establishment of many meteorological institutes in which problems concerned with meteorological data were solved, we have been able to fill up the gap in the study of atmospheric circulation in only a few years, so that the whole picture of the atmospheric circulation of the Northern Hemisphere can now be seen. This kind of work does have academic meaning. Furthermore, we have also been undertaking some meaningful research on the basic theoretical aspects of atmospheric circulation, such as the formation of the average field of circulation, and the physical processes of atmospheric circulation and its controlling factors.

Several of the important accomplishments in research on atmospheric circulation have been selected to be introduced:*

I. The Structure of Atmospheric Circulation

Before liberation, our meteorological workers did some research on the average circulation fields of the lower and upper atmospheres in East Asia. But because of insufficient data their results were quite general in nature. Since 1950, study of the structure of the atmospheric circulation in East Asia began by analyzing isobarometric surfaces in the higher atmosphere and their vertical profiles. Many valuable results which had been overlooked by former workers were obtained.

1. The three-dimensional structure of average circulation in winter: In respect to the structure of circulation, we had already discovered in 1950 that two branches of a jet-stream existed in our atmosphere in winter.[1] One of the two jet streams is located near northern Tibet, the other near southern Tibet. The southern one is the main branch. Its average velocity reaches 80 meters per second. Over the continent, and beyond, the velocity of the jet stream increases with the direction of flow. Through the analysis of a series of maps of vertical profiles near 140°E in respect to the winter of 1950, and by the further understanding of the

*Accomplishments of research on large-scale weather processes and monsoons will be discussed in another article, and therefore are not included here.

circulation structure along the sea coast of East Asia, we obtained in 1951 the following results:2/ (a) the intensity of the jet stream above the East Asian Coast line was very strong; and at its center the velocity of air flow may reach 160 meters per second, while the velocity of the jet stream over Europe or America can seldom surpass 80 meters per second; (b) the jet streams, which are closely related to the distribution of fronts in East Asia may be divided into several components that are southermost and highest. They are very closely related to the fronts. (c) the isothermal surface in the major front is higher than that over Europe and America, and is about equal to that over India. These conclusions have been proved to be correct by recent and ever-increasing observations. In regard to the existence of the two branches of a jet stream, some individuals have also discussed it in terms of analysis of higher atmospheric temperature frequency.3/ They also came to the same conclusion.

Following the course of development of socialistic reconstruction, meteorological development has been growing as rapidly as bamboo shoots sprouting after the spring rains. As many meteorological stations--particularly stations for higher atmospheric observation--have been established as there are trees in the forest. These facilities make it possible for our meteorologists to make further detailed studies on the structure of atmospheric circulation and to discuss the average profile along different meridians.4/

The basic feature of these different profiles is the existence of the two branches of the jet stream. The northern branch is located between 200 to 250 millibras, while the southern branch is above 200 millibars. Their altitudes increase from their upper course of flow to the lower course; and their intensity also increases in the same direction. The intensity of the northern branch is about 45 meters per second at 105°E, and 60 meters per second at 120 E. In the southern branch it is 50 meters per second at 75°E, and 70 meters per second at 120°E. The latitudinal distance between the two jet streams becomes increasingly narrower toward their lower course of flow until at 140°E, the two emerge. Accompanying each of the two jet streams is a large, tilted pressure belt.

Because the two jet streams increase their intensity with their course of flow, the north and south temperature range in the higher atmosphere between 25°N and 35°N in our country also increases with the course of flow of the two jet streams

(i.e., from west to east). The average isothermal gradient in the upper troposphere in winter over the sea coasts of East Asia is much steeper than that of North America. To clarify this point, two profiles along 75°E and 120°E, respectively, are given here.

Figure 1

Average cross section along 75°E (solid lines represent equal rotational [western] wind velocity [meters/second]; dotted lines represent isotherms).

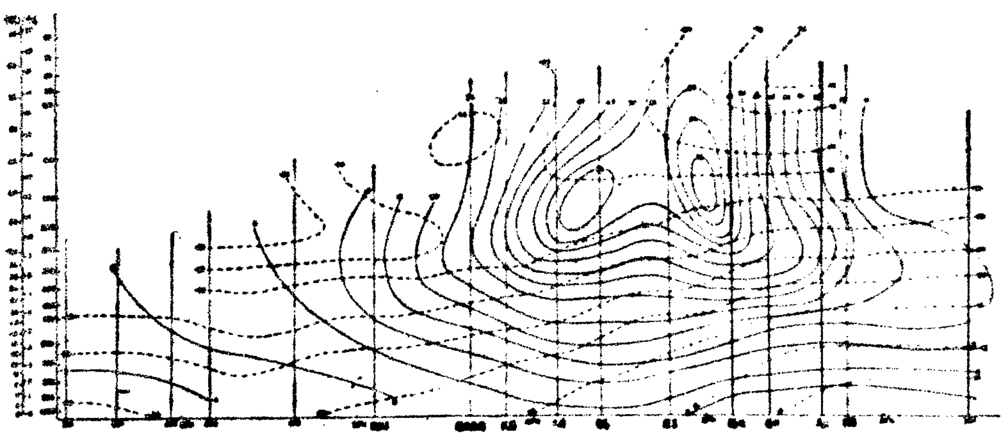

Figure 2

Average cross section along 120°E (the explanation is the same as in Figure 1).

The foregoing discussion is based on each individual annual average. An average profile along 140°E in the five year period from 1951 to January 1955 was also made.5/ During these five years, the annual latitudinal change of the center of the jet stream was from 27°N to 32°N. The annual change of intensity was from 73 to 91 meters per second. If the average profile along 140°E is compared with that along 80°W (in the vicinity of the eastern sea coasts of North America), one may find that in the vicinity of the East Asian sea coast the temperature that existed below 300 millibars is lower than that of the North American eastern sea coasts along the same latitude, whereas wind velocity near the East Asian sea coast is much greater.

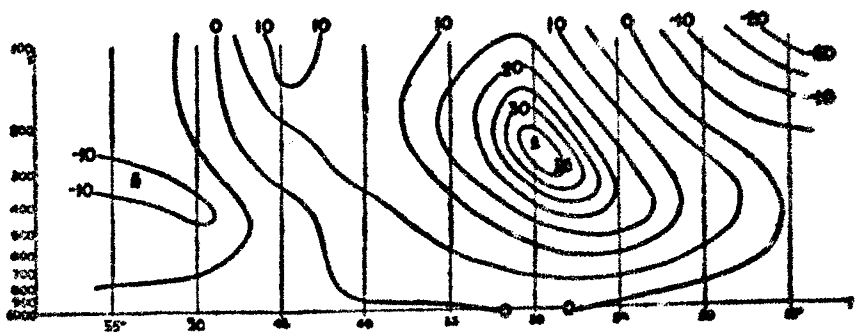

Figure 3a

Differences of wind field in January along 140°E and 80°W on the same latitudes; interval: five meters per second.

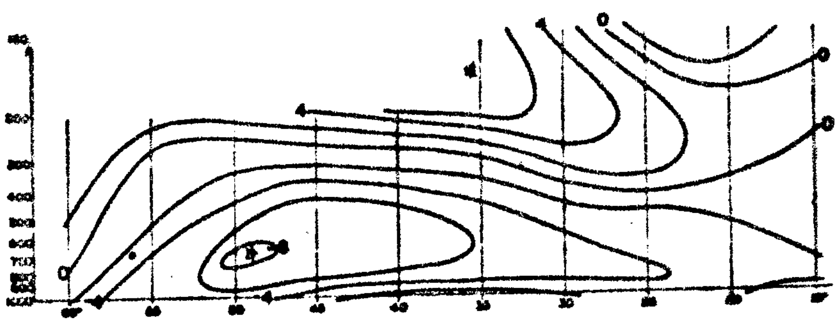

Figure 3b

Differences of temperature in January along 140°E and 80°W on the same latitudes; interval: 2°C.

Figures 3a and 3b show the comparison between the two coastal areas. In recent years, a systematic study was made of the structure of the wind field and temperature field in the profile along each longititude of East Asia.[6]

There still are differences of opinion regarding the existence of the two jet streams, particularly the southern one. The major problem is the relation of the mechanical function of the Tibetan Plateau to the existence of the southern jet stream. Some people have believed that the Tibetan Plateau constitutes a barrier to the prevailing westerlies and thus splits the westerlies into two branches: one to its north and the other to the south.[7, 8] There is a jet stream in every branch of the prevailing westerlies. Therefore, the average position of the southern branch of the jet stream is exactly parallel to the southern slope of the plateau. The year-to-year average position of the jet stream rarely changes.

Since topography can only impede air circulation in the lower atmosphere, one may ask how can the Tibetan Plateau affect the jet stream, which is a phenomenon of the higher atmosphere. According to Taylor's theory, the upper and lower fields of flow in a rotating system always tend to be uniform. In addition to this [tendency], topography can cause the formation of a jet stream in the upper atmosphere due to the process of oblique presence in the atmosphere. Some others have argued, however, that the existence of the two jet streams is not entirely caused by the Plateau, because the same phenomenon also exists in Europe.

In the meantime, some of our comrades working on the Plateau have discovered --as a result of fairly frequent flight observations--that the activities of the jet stream to the north of the Himalayas are very frequent in winter and can move north and south freely without any influence from the Plateau.[9, 10] Thus, they believe that the southern jet stream is simply a subtropical jet stream, and that it is not the southern branch of the same jet stream that had been split by the influence of a high plateau. Obviously this problem needs further study. In the Southern Hemisphere, there is little land surface, and [knowledge of] the distribution of the jet streams in this region would help to solve the problme discussed above.

In regard to the maps of distribution of average isobarometric surface, T'ao Shih-yen has mapped out the average monthly 500 millibars in the higher atmosphere for every month of the year, based on observational records of the higher

atmosphere during the past five years and the weather maps of the Northern Hemisphere which have been published by the United States.[11] This atlas of higher atmospheric conditions by T'ao Shih-yen is comparatively speaking, the most accurate one of its kind, because it correctly indicated the atmospheric circulation in China. For example, the great low pressure trough along the Asian sea coast in winter (January is a representative month, Fig 4) appears more to the west in this atlas than in the weather map published by the United States Weather Bureau; and the high pressure ridge in the central part of Siberia also shows a greater intensity in this atlas than in the weather map of the United States Weather Bureau, or in the one by Scherlag, although it is weaker than in Pogosyan's.

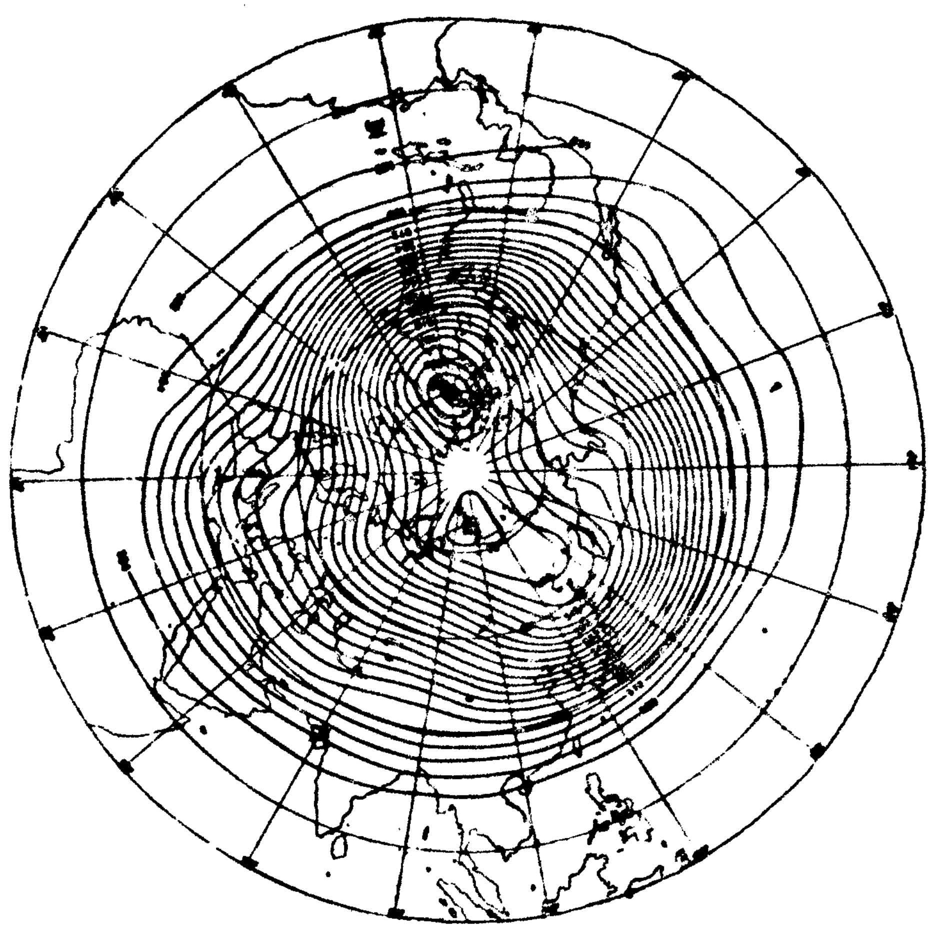

Figure 4
Average 500-millibar altitude in the Northern Hemisphere (January).

In the foregoing we discussed the fact that winter circulation in East Asia is composed of many different types of circulation. These different types of circulation are very important in weather forecasting. With respect to these types of circulation, we have conducted numerous studies since liberation. However, these studies will be introduced in another article and are not discussed below.

Although we have conducted many studies on circulation in East Asia since liberation, our relatively detailed studies on the structure and the processes of development of the different types of circulation are still inadequate. For instance, we still have not clarified the detailed aspects of the structure of wind velocity in the jet stream and the process of its development. Such information is very important to aviation. Due to the rapid development of air navigation, the study of the forms and development of air circulation at 200 kilometers or higher above the earth's surface has important practical value. We need to conduct additional research.

2. The three-dimensional structure of average circulation in summer: East Asia is the world's famous monsoon region. The circulation structure in summer and winter is obviously different. In winter the northwestern and northeastern winds prevail in the lower atmosphere in East Asia. However, the prevailing westerlies control the whole region above 3,000 meters. The norhtward shift of the prevailing westerlies in summer is particularly manifest in East Asia. Either the structure of the field of flow or the situation of the circulation is very different from that in winter. The atmospheric circulation in summer is much more complicated than in winter. Below are presented the principal results of our studies in recent years of the average circulation structure in summer:

In the map of profiles along 75°E, 90°E, 105°E, 120°E, and 140°E from July to August 1956,[12] one can see that the three-dimensional structure of circulation in summer in East Asia comprises three circulation systems: (1) Prevailing westerlies belt--between 40°N and 45°N exist a jet stream of western wind having an intensity of not more than 30 meters per second; (2) eastern low latitude wind belt--in this belt there is a jet stream of eastern wind located between 10°N and 15°N; (3) below the eastern low latitude wind belt in the higher atmosphere eixst the westerlies. This constitutes

the well-known southwestern monsoon.

Figures 5 and 6 are two profiles along 90°E and 120°E, respectively. In Fig 5 we can see that the boundary between eastern and western winds is located to the north of 30°N above the Tibetan Plateau. The southwestern monsoon, in general, reaches northward to the foothills of the Himalayas. On certain days the monsoon can ascend the Tibetan Plateau [13], [14]. If Fig 5 is compared with Fig 6, we can see that the intensity of the jet stream in the westerlies belt does not increase toward its lower course of flow, a phenomenon contrary to that in winter. Furthermore, the intensity of the jet stream shows a tendency to decrease toward the lower course of flow.

In addition, an average profile along 140°E in summer was constructed according to data of many years.[15] The altitude of the jet stream shown on the profile of July is about 200 millibars, while the intensity is 20 meters per second and the location is near 42°N (Fig 7). The annual average center of this jet stream in the past several years varied between 36°N and 44°N, while the altitude varied between 185 and 220 millibars, and the intensity between 22 and 26 meters per second.

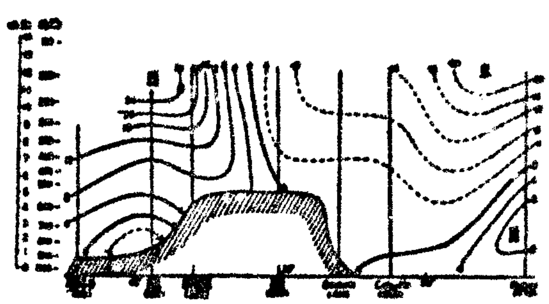

Figure 5

Cross section of wind velocity (meters/second) based on actual observed latitudinal wind direction along 90°E in July-August, 1956.

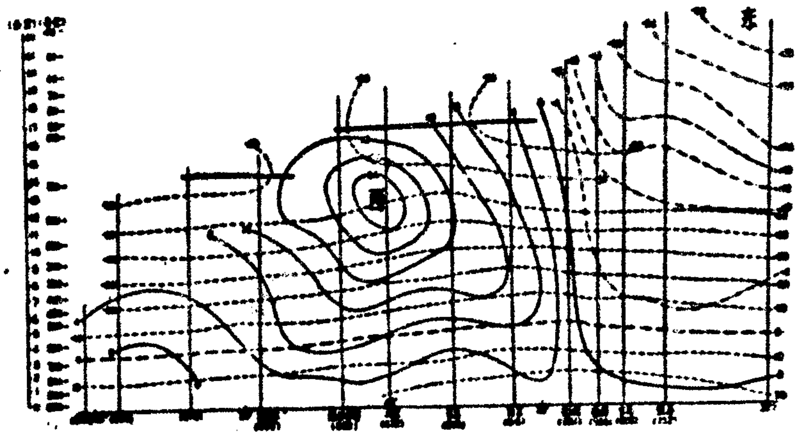

Figure 6

Cross section of wind velocity of latitudinal wind direction (meters/second) and temperature 0°C; the dotted line along 120°E in July-August, 1956.

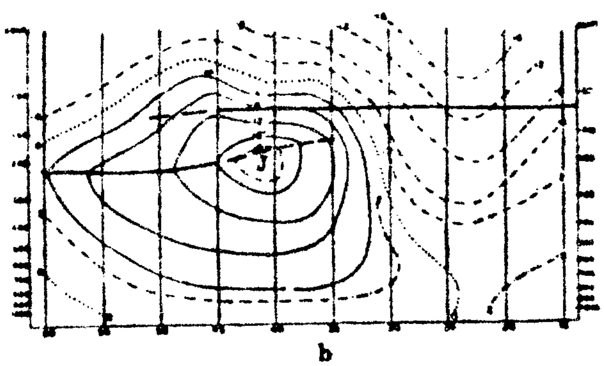

Figure 7

Average rotational wind velocity along 140°E in July. Equal wind velocity line in meters per second; heavy solid line indicates the upper troposphere.

The type of circulation on the isobarometric surface of summer in Asia may use Tao Shih-yen's average map of July as its representative 11/ (Fig 8). In this Figure one can see that there is a subtropical high pressure ridge located between 25°N and 30°N, and enclosed high pressure over the Tibetan Plateau. The latter is smaller than the real pressure there, probably as a result of the inadequate plateau records kept at that time. The low pressure trough near 110°E is shown much more clearly than in maps published by foreign countries.

With respect to the processes of large-scale weather in summer in East Asia--especially weather processes related to summer precipitation, and problems related to monsoons--our meteorologists have much work since liberation. These works will be discussed in another article, and they will not be discussed below.

The greater part of our country is affected by subtropical weather in summer. The weather system of low latitudes also extends its influence to our country. Our research on atmospheric circulation in the subtropical and lower latitude belt is, however, only sporadic. Someone made an initial classification of the subtropical circulation types in summer in East Asia in 1956 and 1957 16/. Some researchers are working on problems of summer precipitation in relation to subtropical summer circulation types 17/. But, as a whole, systematic research on these aspects is still lacking, therefore needs to be greatly extended in the future.

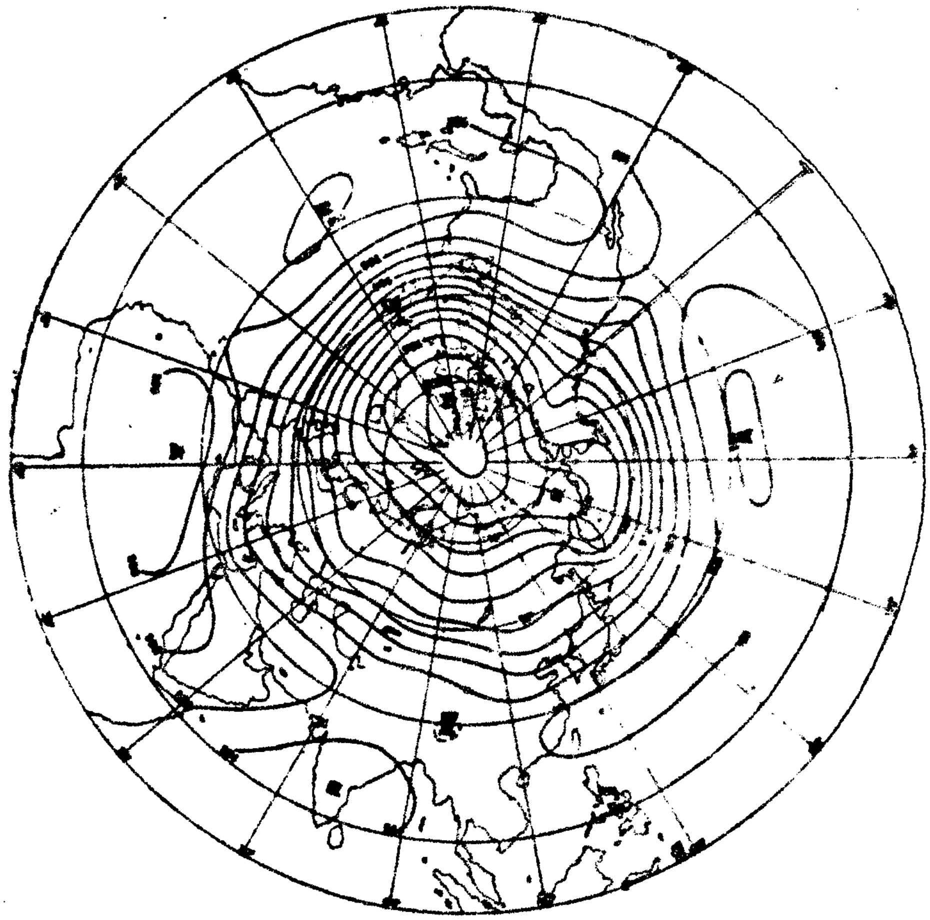

Figure 8

Average 500-millibar altitude in July in the Northern Hemisphere.

II. Seasonal Change of Circulation

The development of agriculture and water conservation urgently require long-range weather forecasting. The Party therefore has requested our meteorologists to continue to conduct research on long-range forecasting. The classification of seasons and knowledge of seasonal changes are necessary to maintain effective long-range forecasting. Some researchers divided the summer into early summer and full summer according to high atmospheric winds and the development of weather processes.[18] The beginning of early summer is the advent of "mei-yu" (plum rains), and full summer begins at the end of mei-yu. This kind of classification conforms satisfactorily with familiar climatic phenomena. Accordingly, the natural seasons in East Asia are five in number: winter, spring, early summer, full summer, and autumn.*

The transition from season to season in East Asia, generally speaking, is of the abrupt type. The advance and retreat of the southern branch of the jet stream in East Asia and the advent of early summer and winter circulation are sudden and precipitous in nature. The southern jet stream forms suddenly in mid-October;[17]; at this moment East Asia is exhibiting its winter circulation type. Similarly, meteorologists in Burma have found the sudden retreat of the southern jet stream to take place at the beginning of June. With respect to the two precipitous changes and the accompanying weather phenomena in our country, our meteorologists have done a considerable amount of research work.[19],[20]

Subsequently, researchers discovered that the two sudden changes in circulation are of large-scale operation in the higher atmosphere of the Northern Hemisphere.[22] At the end of May and beginning of June, there first occurs the sudden northward retreat of the southern jet stream in Asia; this is immediately followed by the occurrence of the same phenomenon in the Pacific, and finally in North America. The difference between Asia and North America with respect to time is about 10 to 15 days. The change in mid-October also occurs at different times in different regions, but it is not as regular as the change at the end of May and beginning of June.

*Recently some researches divided winter into two seasons, and others even into three seasons.

These two sudden changes are not only reflected by the sudden southward or northward shift of the jet stream and wind belts, but also by the two periods of time of change. The higher atmospheric circulation throughout the Northern Hemisphere shows a marked change. Either the location of the major ridges or troughs or their numerical value changes noticeably. Immediately following the sudden change of circulation in the beginning of June, there is the arrival of mei-yu in our country and Japan, as well as the southwestern monsoon in India; immediately after the sudden change in the mid-October, the southwestern monsoon retreats. Furthermore, the atmospheric circulation in East Asia also shows a precipitous change in March.22/ This change usually occurs within a certain period of time after the change in the beginning of June. The same research also indicates that the index of prevailing westerlies and the annual north-south exchange index tend to be constant.

Based on these fundamental phenomena, meteorologists have begun their research on long-range weather forecasting. These research works have enabled us to achieve a further understanding of the long-range weather processes and the nature of atmospheric circulation in East Asia. They illustrate that the change in atmospheric circulation is not gradual but precipitous. Conclusions have been formulated on the characteristics of each natural season and on the processes of seasonal change in East Asia.23/

As long as the seasonal changes follow a regular course, our country will enjoy a normal and ideal climate. But when the seasonal changes are arnmalous,flood or drought will occur in our country. The great flood in 1954 was an example of an anormalous seasonal change. In that year the arrival of the full summer circulation type was delayed, and mei-yu lasted almost two months (June and July) in our country. As a result, the huge Yangtze River flood was the largest in one hundred years.24/ In 1958, the southern branch of the jet stream of Asia remained too long, and the arrival of mei-yu was delayed. Areas along the Yangtze Valley faced the problem of insufficient rainfall.

It has been cited above that the beginning of early summer circulation is the time of the sudden arrival in India of the southwestern monsoon, and also marks the advent in our country of mei-yu in the southern Yangtze. In a further analysis of the change in higher atmospheric circulation during the mei-yu season, some researchers discovered that

the beginning and the end of mei-yu season are quite regular 20/, 22/, 25/. Its beginning occurred during the time that atmospheric wind belts in the higher atmosphere of Asia suddenly advanced northward, and its termination very closely approached the date of the vanishing of the "kuan-yeh" jet stream in Japan, and that of the occurrence of the easterlies.

Although the duration and the date of occurrence of the mei-yu season varies from year to year, its variations retain a consistent pattern. The discovery of this particular phenomenon has been very helpful in forecasting the mei-yu season. There are already detailed analyses on the study of the weather processes of the mei-yu season. 26/ 27/

There have been studies on the arrival of the East Asiatic transitional season;28/ the advent of spring and autumn in East Asia are also very sudden. During the advent of spring and autumn, the decreased or increased quantity of Asiatic air pressure is greater than elsewhere in the Northern Hemisphere. After the beginning of spring, there is a sudden increase in the moving pressure trough and ridge in East Asia. This kind of phenomenon is one peculiarity of the spring circulation of our country. The fact that the rate of change of air pressure in spring is greater than in any other season distinguishes this area from the rest of the world.29/ When autumn begins, the Siberian high pressure area often moves southward and inland on the continent and the hot, low pressure area will then rapidly vanish in our country. The key to the transitional seasons of spring and autumn lies in the sudden change in location of the average high trough and ridge.

We have done considerable work since liberation on the demarcation and variation of East Asian seasons. With regard to this significant meteorological problem, however, we have obviously not done sufficient work. First of all, the study on seasonal demarcation should be continued. Demarcation should be based upon seasonal indications. The seasonal demarcation discussed above was based chiefly on the location of the north-south movement and the latitudinal wind belt (including the jet stream).

We should continue to study whether this indication is related to other kinds of meteorological phenomena. For example, it is all very fine that early summer, derived from the change of location of the wind belt, happens to occur

during the mei-yu season. But what about other seasons? More intensive discussion should be initiated. Specific meteorological processes within each season should also be topics for study. Since an understanding of the change of physics of weather and meteorological processes from one season to another is crucial for long-range weather forecasting, research in this field should be undertaken.

The monsoon is a peculiar feature of East Asia, and we have recently done considerable study on it (relevant conclusions will be described in another article). However, its formation and its processes of development, in relation to atmospheric circulation, still need more discussion.

III. Effect of the Tibetan Plateau on East Asian Atmospheric Circulation

The Tibetan Plateau is the highest and the largest plateau in the world; it is 3,200 kilometers long from east to west, and 1,500 kilometers broad from south to north, and its elevation in winter is more than one-third of the thickness of the troposphere. Such a vast plateau must have an enormous effect upon East Asiatic circulation and upon climate in China. Meteorologists have long devoted attention to this problem. Under the reactionary regime, however, meteorology was merely so much window dressing and could not be developed. On the Plateau, there was only the one ground observatory station located at Lhasa, and no meteorological data were collected. In this poor situation, it was hardly possible to carry on meteorological study. Meteorological conditions on the Plateau thus remained a mystery.

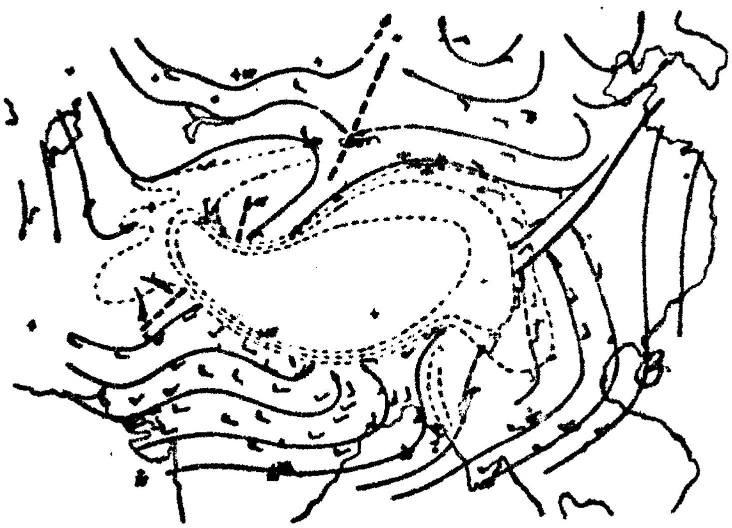

Figure 9

Average flow at 1.5-kilometer altitude in summer (a complete horizontal line represents two meters per second; a semi-horizontal line represents one meter per second. A non-horizontal line represents a velocity less than 0.5 meter per second. No flow lines are shown on the right-hand side because this map is based on data of July 1951-55 (other explanations are the same as in Figure 10).

Since liberation, an observatory station net was rapidly built. With abundant data, study can be carried out in regard to the effect of the Tibetan Plateau upon East Asian atmospheric circulation and upon climate in China. In the past ten years, studies dealing with this problem have been profitably undertaken by our meteorologists. [7/8/13/30-41] Below is a summary of these results:

1. In the prevailing westerlies belt the lower layer of the troposphere in winter is affected by the Plateau, and splits itself into southern and northern branches, which, upon circling the Plateau, head eastward. There thus is very little activity in the Plateau's higher atmosphere; a sub-orindate phenomenon, though directly traversing the Plateau, may be observed in the higher atmosphere. The amount of air over the Plateau is determined by the stability of the air flow. In summer, since the atmosphere is less stable than in winter, there is a large amount of air flow. Figures 9 and 10 represent an average map of flow of summer and winter at a 1.5-kilometer altitude. It may be observed that the partial velocity of average air flow in summer along the topographic slopes is greater than in winter. In winter, the westerlies belt divides itself on the Plateau into two directions--north and south, each of which possesses a jet stream of westerlies. The southern branch is much stronger than the north one. The intensity of both branches of the jet stream increases at the lower course of flow, while all altitudes also increase at the lower course. The latitudinal distance of the two branches diminishes particularly at the lower course and they finally converge over the sea. The average location of the southern jet stream, despite some daily changes, varies slightly in surrounding the southern slope of the plateau.

From Fig 10, we can also see that in winter, due to the division of the westerlies belt, there are two opposite points of impedance formed at the two ends of the plateau: east and west. The velocity of air flow is rather slow at the two points and the weather system is not as evident as elsewhere. A converging area of the two westerlies branches is located along the eastern slope and its lower course. This area of convergence presents a great hindrance to the developmentof low pressure in China. Climatic experiences instruct us that a strong low pressure area rarely develops on the mainland of China (except in the Northeast). Departing seaward from China, low pressure begins to develop. This situation differs from the situation of the North American continent where strong high pressure often occur.

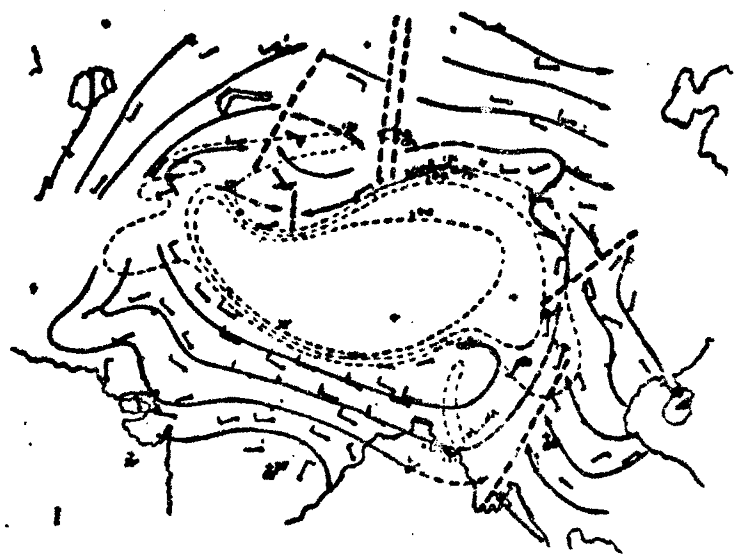

Figure 10

Air flow at a 1.5-kilometer altitude in winter (a complete horizontal line represents four meters per second; a semi-horizontal line represents two meters per second; a non-horizontal line represents a velocity less than one meter per second. The number in parentheses represents altitude (in kilometers); the "Star" directional indicator represents data before 1934; the dotted line represents flow on different altitudes. Fine dotted lines represent topographical contours. The inner circle represents an altitude higher than five kilometers, the middle circle represents an altitude higher than three kilometers, and the outer circle--above 1.5 kilometers.

Another obvious effect of the Plateau upon the weather system is that the huge, extended trough coming from Europe is divided into two branches. The northern branch, which is rapidly moving eastward is either weakened and strengthened upon reaching Lake Baikal; the southern branch either vanishes or moves eastward along the southern part of the Plateau. The situation described above does not suggest that all troughs can never pass over the Plateau. At certain times, during the upsurge of the East Asiatic westerlies, small-scale disturbances are often evident over the Plateau. The case of Los Angeles in North America, however, affects the weather system far differently. We can frequently observe the passage of single, deep, and large troughs over Los Angeles in an eastward direction.

In respect to the circulation of horizontal westerlies wind on the windward side of the Mongolian-Sinkiang Plateau flows upward, and increase pressure thus results; on the leeward side, the wind moves donward, and the pressure thus decreases. It appears, therefore, that the trough or low pressure area tends to vanish in ascending the Mongolian-Sinkiang Plateau, while the ridge or high pressure area is strengthened over the Plateau. The situation is reversed on the leeward side. All these findings were based on observations.

The Tibetan Plateau also affects the velocity of wave momentum. It is observed to be more rapid in the northern slope, slower on the southern slope. A theoretical explanation is given in the article on meteorological dynamics in the present issue.

On the basis of theoretical calculations, the formation of a huge trough along the Asiatic seacoast in winter is closely related to dynamic functions in East Asia.

2. Wind direction in summer differs from that in winter; thus the effect of the plateau upon circulation also varies that is, seasonal changes exist because of the effect of topographic mechanical dynamics on circulation. In this respect, very little attention was given in foreign studies to topographic dynamics. The winter phenomenon described above rarely appears in summer. The southwestern monsoon, obstructed by the Arakan Yoma from north to south and by the southern rim of the Tibetan Plateau, is forced to assume a cyclonic movement. This type of cyclone is related to the average location of the Indian low pressure, which can exist

in India but not in the Arabian desert which has an extremely high temperature.

There exists another theory on the formation of the hot, low pressure area: in summer climate belts shift northward, and in the India-Burma region--located in a converging region of continental subtropical high, Pacific subtropical high and the cooler equatorial high pressure belts--the India "hot low pressure" occurs on an intratropical front instead of at the center of the hot region. We thus know that the so-called Indian hot low pressure is not merely caused by the effect of thermal dynamics, but also by mechanical dynamics.

3. With regard to the effect of thermal dynamics of the Tibetan Plateau, calculations may initially confirm that it is a source of heat in summer and that in winter its southeastern portion is still a heat-source. As to the rest of the Plateau, our insufficient data cannot provide definite answers. Since the Plateau is a source of heat in summer, it is no longer situated in the westerlies belt; since a subtropical high pressure ridge cuts accross the Plateau, a closed high pressure area is thus easily formed above it. This phenomenon has been justified recently observed data.

The daily change of wind direction surrounding the Plateau represents another effect of thermal dynamics of the plateau. As revealed in the statistics of observational data, the afternoon average wind direction in stations in the vicinity of the Plateau indicates a diversified direction toward the Plateau. Around sunrise, there is diversified wind blowing toward the Plateau. Therefore, in the afternoon the converging field of flow occurs, while the field appears around sunrise, and the numerical scale of convergency (divergency) is rather large.

These results of research have furthered our understanding of East Asian atmospheric circulation, and they are of both academic and practical value.

A recent book, "Meteorology of the Tibetan Plateau," by comrades of the Second Division of Geophysical Studies of the Academia Sinica and certain meteorologists should be mentioned here. This book gives a summary of meteorological studies of the Tibetan Plateau and presents intensive discussions on forms of circulation in the atmosphere of

the plateau, climate near the ground and climate of free air, climate of individual stations, and climatic system. Since the authors are equipped with abundant practical experience, they thus provide a detailed description in the book rather than a mere recording of daily data.

We have accomplished much on the effect of the Tibetan Plateau upon atmospheric circulation during the past ten years, although such attainments have been far from sufficient. Numerous observatory stations were rapidly built on the Plateau; nevertheless, they are still insufficient in terms of the size of the Plateau. The eastern part in particular remains a blank. As more stations are built, therefore, our study should be expanded. In the past more work was done in winter, and less in summer. From now on, more should be done in this field. In addition, theoretical study on the effect of the Plateau should be urgently developed, in view of our past studies dealing cheifly with climatical aspects.

4. Fundamental Theories

Intermediate and long-range forecasting which is closely related to large-scale circulation, is essential to the ever-expanding socialist reconstruction. One of the keys leading to effective intermediate and long-range forecasting relies, therefore, upon an effective study of atmospheric circulation. A clear understanding of the basic theories of atmospheric circulation is certainly necessary. In the past several years we have done considerable work in this field.

In recent years, meteorologists, home and abroad, have done considerable work on the problem of the maintainence and continuation of latitudinal circulation (east and west wind belt). Differences of opinion are numerous, among which the problem of longitudinal circulation has been the focal point. Theoretically speaking, one school of thought teaches that latitudinal circulation does not necessarily depend on longitudinal circulation, and that the very existence of longitudinal circulation is even doubtful. Another school of thought, nevertheless, affirms the existence of longitudinal circulation, as well as its functions. It thus becomes necessary to support the existence of longitudinal circulation by actual evidence.

In 1950 [42], for the first time, man indirectly proved the existence of the Hadley longitudinal circulation [Hadley Ring] by means of data on sea winds. But in 1956 [43] we plotted a graph of air flow distribution along a longitudinal plane by utilizing Buch's actual observational records (Fig 11). Longitudinal circulation clearly appears in this graph. Its actual existence is thus established.

The maintaining function of longitudinal circulation in relation to latitudinal circulation has been estimated.[44] The result indicates that the role of longitudinal circulation in low latitudes should not be overlooked. But this phase of study, like other related studies in the past, stressed only the problem of transmitting angular momentum to high latitudes. But the angular momentum is mainly involved in the transference from a high to a middle atmosphere. How would it be transmitted from the near-ground layer of the easterlies belt (the origin of angular momentum) to a high atmosphere? The Hadley type of circulation may serve as an explanation. This type of circulation has great absolute angular momentum of air. It can draw Equatorial air with enormous absolute angular momentum to a high atmosphere; at the same time, the tropical air has a smaller absolute angular momentum. Thus, there is excessive angular momentum to be transmitted to a high atmosphere.

Since the sum of the Earth's and the atmosphere's angular momentum is a constant, as the total angular momentum changes in the atmosphere, there must be a change in the angular velocity of the Earth's rotation. In winter (in the Northern Hemisphere) the total atmospheric angular momentum of the whole Earth is larger than in summer, and the angular velocity of the Earth's rotation is smaller than in winter. Although the total angular momentum of the Earth's atmosphere is larger in winter, nevertheless, at 650 millibars the average westerlies circulation is larger in summer, and smaller in winter. Thus, the atmosphere's and the Earth's angular momentum are interchangeable.

Moreover, the phenomenon conforms to the demand that the entire Earth and atmosphere remain constant. It explains, too, that in winter and in summer (in the Northern Hemisphere) the changing direction of intensity of westerlies circulation advances in an opposite direction. The intensification of westerlies circulation near ground level indicates increased consumption angular momentum in the atmosphere and a reduced effect in producing angular momentum (disregarding the effect of mountain ranges). The total angular momentum in

the atmosphere therefore decreases. The diminution of westerlies circulation near ground level signifies a contrary change.

Figure 11

Average longitudinal circulation of the Northern Hemisphere in 1950.

The 850, 700, 500, 300, 200 and 100-millibar longitudinal wind velocities along longitudes 10°, 20° ... 70° were taken from Buch. 1,000-millibar longitudinal wind velocities along 0°, 10° ... 30° were taken from Riehl and T.C. Yeh. Numbers within the circle are taken from Starr and White's longitudinal wind velocity on a standard isobarometric surface along 42.5°. The numbers for 850, 700 and 500-millibars along 10°-20°, 20°-30°, ... etc., are from the Chien Chih wind velocity (arrow indicates the direction of the Chien Chih movement; the unit for longitudinal wind velocity is meters per second, and the Chien Chih wind velocity unit is millibars per second.

The balancing process of atmospheric kinetic energy is a significant problem of atmospheric circulation. First of all, there should be estimated the total kinetic energy in the atmosphere, the average rate of consumption, and the average rate of productivity. The average kinetic energy of the upper troposphere in middle latitudes of the Northern Hemisphere calculated by daily records (1945 to winter 1946) 46/ is double Spar's calculation by means of a year round average map. Furthermore, it was indicated that the disturbance of kinetic energy is greater than the kinetic energy of basic westerlies circulation. The

"efficient potential energy" of the atmosphere of the Northern Hemisphere, as well as the distribution of the rate of consumption and the rate of production of average kinetic energy in the atmosphere of the Northern Hemisphere were further calculated. Calculations were also made on the transformation of various types of energy in the same area. A cyclic process of atmospheric energy was thus attained. The balancing process of atmospheric kinetic energy was also studied;[47],[48] this has already been described in our discussion of results achieved in meteorological dynamics. There is no need for repetition here.

Through the process of air pressure $\left(\iint_{S_1} wp\,dx\,dy,\ \iint_{S_2} vp\,dx\,dz\right)$, atmospheric kinetic energy is transferred from lower layers to a higher atmosphere, and from south to north (in the Northern Hemisphere). Here v and w are the north-south and vertical wind velocity, respectively; P is air pressure; S_1 is a surface of equal elevation; S_2 is the vertical plane through a certain latitudinal circle. Since

$$\iint_{S_1} wp\,dx\,dy = R\iint_{S_1} w\rho T\,dx\,dy,\quad \iint_{S_2} vp\,dx\,dz = R\iint_{S_2} v\rho T\,dx\,dz.$$

Here, R is a constant; P is air density; T is air temperature; the process of balancing of kinetic energy can be connected with the transfer of heat energy.

From the foregoing discussion, the relation of various kinds of physical processes of atmospheric circulation do not seem to be very closely related, but actually they are so. For example, heat energy has to be transferred to the north and to the upper atmosphere in order to balance the cooling which results from radiation. These two different ways of transferring energy may be accomplished by a large-scale disturbance. From the above equation, the consumption of the balanced kinetic energy, as far as the whole atmosphere is concerned, requires: $\int p\,\mathrm{div}\,v\,dv > 0$.

This is equivalent to $-\int T\frac{d\rho}{dt}\,dv > 0$; in other words, T and $\frac{d\rho}{dt}$ are negatively related and T and W (vertical velocity) are positively related ($\overline{Tw}>0$). . Therefore, in the process of upward transference of heat, the necessary change of potential energy into kinetic energy is materialized.

It can be derived that in the course of a large-scale disturbance, a positive relation exists betwewn u and v; this also involved the northward transfer of angular kinetic energy. This northward transfer of angular kinetic energy is also produced by the unstable disturbances.

From the foregoing discussion one can observe that the processes of various kinds of major physical energy are closely related. The bridge that connects these different processes is the unstable disturbances.

The physical process of resistant turbulence is opposite to that of unstable turbulence. Thus in the cycle of the development of turbulence and resistance, on an average, there will be no northward and upward transference of heat energy, no transformation of potential energy to kinetic energy, and no northward transference of momentum. But due to the existence of friction, in the process of the development of turbulence and resistance, the transference of various types of physical energy works in an opposite way. This causes under normal conditions, the northward transference of heat energy, transformation of potential energy into kinetic energy, and the northward transference of angular momentum.

The unstable large turbulence not only bridges various balancing processes of physical energy, but also strongly affects the formation of easterlies and westerlies wind belts, average longitudinal circulation, and jet streams, On the other hand, the occurrence and development of large-scale turbulence is also continuously influenced by wind belts. Therefore, the westerlies belt average longitudinal circulation, the jet stream, and large-scale turbulence are systematically inter-connected. One can see that the important phenomena of atmospheric circulation are unified and mutually controllable.

The details of the discussion may be found in the book: "Fundamental Problems of Atmospheric Circulation"49/. The above-mentioned conclusion was verified by the analysis of individual case study. In the meantime, this research also emphasized the fact that many important physical processes in the atmosphere maintain opposite characteristics in the course of change from a high index to a low index, or vice versa (such as heat energy, the balance of kinetic energy and angular momentum, transformation of turbulent kinetic energy to turbulent potential energy, etc). The average

physical processes in the atmosphere are composed of these two types of opposite processes.

With regard to why there are changes in circulation of a high and low index in atmospheric circulation, the theory of large-scale instability is involved. We also conducted certain researches on this aspect, which are discussed in the article entitled "Research in Dynamic Meteorology in Our Country." Therefore, repetition is not necessary.

With respect to annual change in atmospheric circulation, some persons [20], on the basis of monthly changes in the 500-millibar circulation in the Northern Hemisphere, discussed the characteristics of change in atmospheric circulation and, on the basis of combined causes of mechanical dynamics and thermo dynamics, discussed the caused for the formation of circulation; at the same time, they pointed out the difference in effect of wide-scale topographic mechanics in East Asia and North America. Some researchers also studied the annual change in westerlies circulation from the point of view of radiation; they also constructed a map of annual change in the 500-millibar average westerlies on each latitude of the Northern Hemisphere; in addition, a map was compiled on the annual change in solar radiation and effective radiation on each latitude. These two distributional maps resemble each other. Therefore, the change in average westerlies on each latitude is basically determined by the change in radiation.

Finally it should be pointed out that the study on atmospheric circulation by laboratory models has begun. In the laboratory a study has been made on the formation of large system wind and temperature fields. This work was conducted by the Department of Geophysics of Peiping University.

Conclusion: We can see from the above discussion that our study on atmospheric circulation since liberation has had results. Under the guidance of the Party and the State our study has progressed satisfactorily. We are confident that we shall raise the level of this kind of research in the future.

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